NON LINEAR STATIC ANALYSIS OF RC FRAMED BUILDINGS WITH SETBACKS

B.Satish kumar [1], G.Swarna[2]
1- Student of Civil Engineering, Samskruti college of engineering and technology
2- Assistant professor, Department of Civil Engineering,Samskruti college of engineering and technology

Abstract- Analysis of the structure shall be conducted to determine the distribution of forces and deformations induced in the structure by the design ground shaking and other seismic hazards corresponding with rehabilitation objectives. The analysis shall address the seismic demands and the capacity to resist these demands for all the elements in the structure that are either essential to the lateral stability of the structure (primary element) or to the vertical load carrying integrity of the building. Major structural collapses occur when the building is under the action of dynamic loads which includes earthquake loads. In these modern days most of the structures are involved with architectural importance and hence many structures in the present scenario have irregular configurations both in plan and elevation. This in future may subject to devastating earthquakes. Hence, it is necessary to identify the performance of the structures to withstand against disaster for both new and existing one.

This study aims at evaluating and comparing the response of G+10, G+15, G+20 systems with vertical irregularities as described by the ATC-40 and the FEMA-273 using nonlinear static procedures, with described acceptance criteria. The methodologies are applied to G+10, G+15, G+20 systems with vertical irregularity with bracings and with masonry struts. The non linear response of structure with vertical irregularity has been done using SAP2000 16 with intent to evaluate importance of several factors in the non linear static analysis which includes time period, displacement, base shear etc.

Performance may relate the strength level achieved in certain members to the lateral displacement at the top of the structure, or bending moment may be plotted against plastic rotation. Results provide insight into the ductile capacity of the structural system, and indicate the mechanism, load level, and deflection at which failure occurs.

INTRODUCTION

Problem Description

Structures mostly get affected severely when an unexpected loads acts on it and this type loads are often classified into dynamic loads which includes wind, earthquake, blasts etc. This project deals with the effect of earthquake on a structure, which itself has huge devastating potential if occurred at higher intensity. Earthquake may occur due to the presence of fault or fault lines, where uneven edges of two tectonic plates get grind against each other which mostly happens in the middle of oceans and the Himalayan regions too. Tectonic plates keep moving continuously with extremely slow motion that even can't be noticed most of the time. But every once in a while these tectonic plates suddenly jolt into a new position and the energy released in the process leads to an earthquake. It starts at a point inside the earth's crust called as the focus where the moving plates are in contact, and then travels through the ground as very low frequency sounds in different directions called shock waves or seismic waves. The extent of damage is greatest at a place called the epicenter, which is the point on earth's surface above the focus, which is also the point of origination of an earthquake. Earthquakes continue until all the energy released from an earthquake has been dissipated. Even then, there is possibility of further occurrence of earthquake, known as aftershocks, which will happen for some hours or even days afterward.

When earthquake strikes a multi storied structure the damage generally gets initiated at the weak locations in the structure. The behavior of multi- storied framed structure basically depends on the shape and size of the structure which may vary in mass, stiffness and strength in both horizontal and vertical directions. Sometimes these weaknesses might be due to the discontinuities created within the structure i.e. between adjacent storey's which are often associated with variations in frame geometry of the structure along the height. The most general type of vertical geometrical irregularity is due to the provision of setbacks which can be sudden change in the lateral dimension of the structure along the height at certain levels. These types of structures can be classified as setback structures or structures with vertical geometrical irregularities. These types of structures are quite often in the modern days due to its aesthetic and functional architectures, as such structures provide adequate day light and ventilation to the occupants of the lower storey's instead of closely spaced tall uniform structures. Height wise change in the mass and stiffness alters the dynamic characteristics of the structure and it has been observed that higher mode participation and inter storey drifts in upper floors are quite significant.

Analysis and designing methods of structures are mostly directed by the provisions of the code. In static case the structures are subjected to low loads for which it largely remains in the elastic range unless a strong seismic event occurs, where the forces acting on it pushes the structure to behave beyond its elastic range. Although the building codes provide a reliable insight of actual performance of individual elements, but the performance of the structure as a whole is still a non reliant part of the codes under large forces. Hence, performance based design is the new dimension in the seismic design philosophy. The Concept of seismic design is to provide building structure with sufficient strength and deformation capacity to sustain seismic demands imposed by ground motion with adequate margin of safety. Even if the probability of occurrence of earthquake within the life span of structures is very less, strong ground motion would generally cause greater damage to the structure. For designing the structures for this combination having less probability and extreme loading, a criterion is adopted in such a way that a major earthquake, with a relatively low probability of occurrence is expected to cause significant damage which may not be repairable but not associated with loss of life. Due to this the performance based design of structure is gaining popularity which predicts the actual performance of the structure as a whole to considerably accurate levels. Some of the countries even have separate codes for this type of analysis; however there is no Indian code which deals with these types of analysis.

The performance based analysis ability to predict the performance of structure to acceptable level makes it one of the more followed methods. Performance-based design differs from repressive design in that designers can use alternative solutions as long as they reach the stated goal of the performance-based code. The goal of a performance-based code is usually very broad and usually differs from prescriptive codes which give out exact steps that have to be followed to reach the objective. However, performance based methods are already being used in automobile and airplanes. It can be poised as one of the basic methods (to understand performance of structure under complex loading) for design and delivery of earthquake resistant structures. Recent advances in the performance based design have brought the non-linear static analysis in the forefront. Static Pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

Non-linear static analysis has become widely used performance based design tool for seismic evaluation of existing and new structures. It is assumed that non-linear static analysis will provide adequate information on seismic demands induced by the design ground motion on the structural system and its components. The aim of the non-linear static analysis is to estimate the expected performance of a structural system by evaluating its strength and deformation demands under the action seismic loads by developing a plot between spectral displacement and spectral acceleration which obtained by using the conversion of ADRS format. These are compared to available capacities at the targeted performance levels.

Objectives of Study

Depending on the literature review presented later, the principal objectives of the present study have been identified as follows:

To predict the response of multistory RC framed structures with vertical geometrical irregularities by considering different pushover cases. And examine performance of the structure by identifying the weak zones with two different load patterns in the structure by nonlinear static analysis for different storey height (G+ 10 storey's, G+ 15 storey's, G+ 20 storey's).for the cases under consideration.

To compare the performance of the structure with and without addition of x masonry and steel bracings.

The analysis is being carried out with the help of SAP 2000 and their results are compared in terms of base shear and storey drifts.

LITERATURE REVIEW

Introduction

This chapter involves on various research papers for the non linear static analysis of RC framed buildings with setbacks. These research papers help in understanding the main aim of the project, each writer gives their own conclusion saying that what types of setbacks should be considered and what type of bracing system should be used.

The literature subject collected on the subject is classified into four groups and represented below with their respective authors and year of publications.

Based on Vertical Irregularities

Ramesh et al (2014)

In this study they have considered buildings with vertical irregularities and analyze it under earthquake and wind load basically called as linear static analysis using STAAD as platform for computer based analysis. The buildings under consideration were one regular building and other with vertical geometrical irregularity with first ten floors as 6X6 bay and later ten floors as 2X2 bay at different location (center, corner and left edge of the building).

The roof displacement at all corners of the regular frame is same and even no tensional effect has been observed due to symmetry. In case of irregular vertical building the responses are less at bottom floors and more at top floors than in regular building. For a vertical irregular building frame, where corners bays at top floor, the response in positive direction of the corner column is more than in negative direction. Hence the torsion effect is more in positive direction than in negative direction. In vertical irregular building there is a sudden increase in drift from tenth floor to eleventh floor. But maximum drift is observed between eleventh and twelfth floor.

Based on Masonry Infill Wall

Saraswathy et al (2014)

A twelve storey RC framed building with masonry infill wall is considered in the present study. The building has overall dimension of 24m × 12m, with 8 bays in the larger direction and 3 bays in the smaller direction. Fig. 3 shows the 3D view of building models with and without setbacks, generated using SAP 2000-12. Set back ratios were maintained as 0.27 and 0.40.

Fundamental time period of setback buildings are found to be always less than that of similar regular buildings and it is found to depend on the setback ratio and storey level at which irregularity is introduced. The top storey drift increases with setback ratio; maximum storey drift is found for the building with greatest setback ratio, near to the storey where irregularity is introduced. It was found that the performance point changes due to the presence of irregularity. The base shear is found to decrease with increase in setback ratio. Roof top displacement depends on setback ratio of the buildings but it is found to be independent of the storey level where irregularity is introduced.

Based on Steel X Bracings

Khoshnoudian et al (2008)

This paper investigates the accuracy of the modal pushover analysis to estimate the seismic performance of high rise buildings. The effects of structural irregularities in stiffness, strength, mass and combination of these factors are considered. In other words reliability of the modal pushover analysis (MPA) has been verified by defining a referenced regular structure for comparison between MPA and nonlinear dynamic analysis. In the study, one-bay, hypothetical sixteen-story steel moment resisting frame selected as reference frame. A story height, of 3.5 m was assigned at all floors. Hence, the structures with the height of 56 m studied herein are potentially active for inelastic seismic response. Modal pushover analysis is the method used to analyze the models under study.

The MPA procedure seems to produce results that are somewhat more reliable than those obtained from single load vectors in FEMA. However, it is readily apparent that the accuracy of these depends upon the parameter of interest (e.g., drift, plastic hinge rotation) the characteristics of the structure and the details of the specific procedure. It is also possible that future development of the basic MPA procedure may improve predictions further. The effects of mass irregularities, stiffness irregularities, and strength irregularities are evaluated for seismic demands. Vertical Mass irregularities have known to be in smaller degree of attention due to change at upper stories. Effects of vertical irregularities generally increased when irregularity conducted to base or lower stories.

Conclusion

From the above literature it is noted that the irregularity in elevation of building reduces lateral forces resisting capacity of the structure which in turn reduces the performance of the building and there is also decrease in deformation or displacement of the building.

The assessment of non-linear behavior of the structure is difficult as they have relied on the empirical formulas.

A structure cannot be made earthquake proof as the intensity and the direction of the earthquake is guaranteed, it can't even be predicted precisely; but it can be strengthened to such a level that it can withstand with minimum damage. Therefore different type of bracings are considered and analyzed to find the minimum damage.

PUSHOVER ANALYSIS

Introduction Analysis is of two types Linear Static Analysis and Non Linear Static Analysis. Linear analysis performed assuming that materials behavior is linear and it's performed in two methods Equivalent Static Method and Response Spectrum Method. Non-linear analysis is performed assuming material behavior is non-linear and is performed on base of two different methods Pushover Analysis and Time History Analysis.

Methods of Analysis

For seismic performance evaluation, a structural analysis of the mathematical model of the structure is required to determine force and displacement demands in various components of the structure. Several analysis methods, both elastic and inelastic, are available to predict the seismic performance of the structures.

Equivalent Static Analysis

The force demand on every component of the structure is obtained and compared with available capacities by performing an elastic analysis. Elastic analysis methods include code static lateral force procedure, code dynamic procedure and elastic procedure using demand-capacity ratios. These methods are also known as force-based procedures which assume that structures respond elastically to earthquakes.

Response Spectrum Method Response Spectrum is the plot between time period and the response quantity (which may vary depending upon the study). According to the Indian code response spectrum method is applied to those regular building higher than 40m in height in Zones IV and V, and those higher than 90m in height in Zones II and III. Irregular buildings higher than 12m in Zones IV and V, and those higher than 40m in height in Zones II and III.

This concludes that the procedure works well when the building is regular in plan and elevation. The advantage of response spectrum analysis over equivalent static analysis is that multiple modes can be considered at once. This is required in many building codes for all except for very simple or very complex structures

The procedure of dynamic analysis of irregular type of buildings should be based on 3D modeling of building that will sufficiently represent its stiffness and mass distribution along the height of building so that its response to earthquake could be predicted with sufficient accuracy. The procedure involves calculation of mode shape using characteristic equation also called as Eigen equation. Modal participation factors are obtained and according to the prospects of the code mass participation of the building in the first mode must be greater than 90%. And lateral forces for different mode shapes are calculated using formulae which is combined to represent the peak response using three approaches mentioned below.

1.Maximum Absolute Response
2.Square Roots of the Sum of Squares (SRSS)
3.Complete Quadratic Combination (CQC)

The result of a response spectrum analysis using the response spectrum from a ground motion is typically different from that which would be calculated directly from a linear dynamic analysis using that ground motion directly, since phase information is lost in the process of generating the response spectrum.

In cases where structures are either too irregular, too tall or of significance to a community in disaster response, the response spectrum approach is no longer appropriate, and more complex analysis is often required, such as non-linear static analysis or dynamic analysis.

How does Non linear analysis differ from linear analysis

Response spectrum analysis can be used for linear dynamic analysis of tall buildings, but not for nonlinear. The main reason is that response spectrum analysis depends on superposition, which does not apply for nonlinear behavior. It is necessary to use step-by-step integration, also known as time history or response history analysis.

For linear analysis all structural components are elastic, and only elastic properties are needed for analysis. For nonlinear analysis, some components can yield, and additional inelastic properties are needed for these components. These properties are more complicated than the elastic properties.

Non linear Analysis

Structures suffer significant inelastic deformation under a strong earthquake and dynamic characteristics of the structure change with time so investigating the performance of a structure requires inelastic analytical procedures accounting for these features. Inelastic analytical procedures help to understand the actual behavior of structures by identifying failure modes and the potential for progressive collapse. It provides better insights to assess the risk of a building during earthquake. This in turn leads to economical design and retrofitting of building.

Non linear analysis procedures basically include inelastic time history analysis and inelastic static analysis which is also known as pushover analysis. The inelastic time history analysis is the most accurate method to predict the force and deformation demands at various components of the structure.

Time History Analysis

Time history analysis provides response of structure under loading which might vary according to the specified time function. The forces that are included in time history analysis are inertia, elastic and damping. In time history analyses the structural response is computed at a number of subsequent time instants. In other words, time histories of the structural response to a given input are obtained ad a result. In response spectrum analyses the time evolution of response cannot be computed. Only the maximum response is estimated.

Pushover Analysis

Practicing engineers use inelastic analysis procedures for seismic evaluation and design and upgrades of existing buildings and other structures, as well as design of new construction. The practical objective of inelastic seismic analysis procedure is to predict the expected behavior of the structure in future earthquake shaking. This has become increasingly important with emergence of performance based engineering as a technique for seismic evaluation and design.

Single mode load vectors:

Figure shows the distribution of different types of loads on to structure as shown below:

Concentrated Load: The Simplest assumption for the load vector is a single concentrated load normally at the top of the structure.

Uniform: A uniform load vector assumes that the acceleration is the MDOF model is constant over its height. This alternative is sometimes termed as rectangular.

Triangular: A triangular shaped vector assumes that the acceleration increases linearly from zero at the base to a minimum at the top of the MDOF model.

First Mode: The first mode technique applies accelerates proportional to the shape of the first mode of the elastic MDOF model.

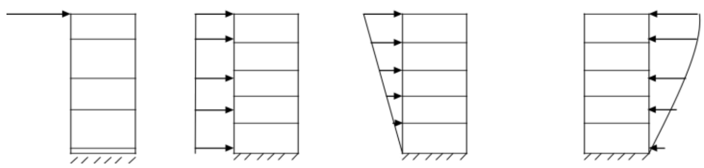

Figure: Types of load vectors

Tools for Pushover Analysis

Many software's are available on which pushover analysis can be carried out, they are

1.STAAD PRO
2.ETABS
3.SAP2000

In this project the analysis is carried out using SAP2000 as it can provide most productive solution from a 2D frame to a complex 3D model for nonlinear analysis. Advanced analytical techniques provide step by step deformation; Eigen and Ritz analyses based stiffness of nonlinear cases. It is finite element software which works with complex geometry. It also has by default all material properties and codes like ATC 40, FEMA 356, FEMA 440, IS 1893 (part 1) : 2002 so as to facilitate easy and quick solution for a set of boundary conditions.

SAP2000 can be used for analyses of any structure from buildings to truss, bridge, stadiums, chimneys, bunkers, silos etc. and even has predefined templates for those. Whereas, ETABS is subjected to cater the analysis requirements of buildings, however all types analyses performed in SAP2000 can also be performed in ETABS; it even requires lesser parameters to perform analysis when compared to SAP2000 due to which it might overlook the minute details that may be quite effective in output of the analysis.

Procedure

As discussed in the previous chapters the main objective of the pushover analysis is to obtain the pushover curve under increasing lateral load along the height of the building for an assumed force distribution and displacement pattern. It is generally assumed that behavior of the building is controlled by the fundamental mode shape and the predefined pattern is expressed either in terms of story shear or in terms of fundamental mode shape.

By increasing the magnitude of lateral loading according to the assumed loading pattern non linear behavior of the structure is observed and weak links and mode of failure of the building is identified. In addition, the procedure is also used to deduce capability of the structure to withstand predefined input motion in terms of response spectrum. Recent modifications to the pushover analysis were made so as constitute the effect of higher mode shapes which is quite significant for irregular structure.

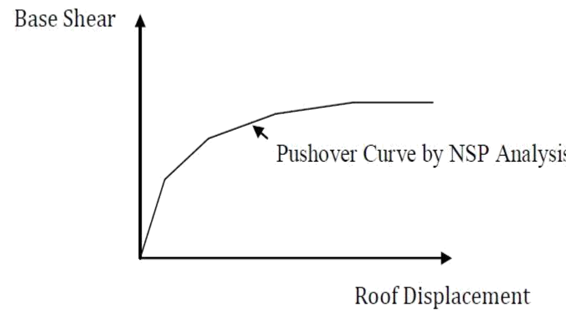

Figure: Pushover Curve

METHODOLOGY

Introduction

Calculation of width of strut depends upon on the beams and columns around the infill and their stiffness and the results are obtained using the expressions as illustrated earlier. As the stiffness of the beams and columns around the infill changes the width of the strut keeps changing accordingly. The depth of the strut is kept as 250mm i.e. equal to the thickness of the infill.

Details of Models

Details of model such as each and every property model have been displaced.

- Type of Structure : Special moment resisting frames
- Number of stories : G+11, G+15, G+21
- No. of bays in X - direction : 10
- No. of bays in Y – direction : 10
- Bay width : 5 m
- Floor height : 3 m
- Depth of Slab : 125 mm
- Beams size (d mm x b mm) : 450X300,450X450, 600X450
- Column size (mm x mm) : 450X450,600X600,600X900
  900X600,1000X1000,
  1200X1200
  1500X1500
- Thickness of Infill : 250 mm

- Concrete : M25
- Steel : Fe 500
- Infill material : Masonry
- Density of Concrete : 25KN/m³
- Density of Infill : 19.5 KN/m³
- Type of Soil : Medium
- Damping : 5 %
- Zone : V
- Zone factor : 0.36

Diagonal Strut Considering the Stiffness of Infill

Masonry infills are the most common part of structure anywhere in the world. The infill walls are constructed as non structural members as it is constructed after erection of beams, columns and slabs. Although infill walls are not desired to participate in the structural importance of the building, they do resist lateral loads and substantially participate in the structural action. In addition to this, they possess strength and stiffness which has significant effect on the performance of the building under the action of dynamic loads.

The purpose of masonry wall is just to create partition inside the building but there has been general agreement over the fact that infill imparts additional load resisting capacity to the structure as shown in Fig 1 in (a) and (b). It even reduces the lateral deflections and bending moments in the frame thereby decreasing the probability of collapse and increases the base shear of the structure. The seismic performance of structure depends primarily on the mass and stiffness of it, when the stiffness of wall is considered the overall stiffness of structure increases which in turn contributes towards reducing storey drifts.

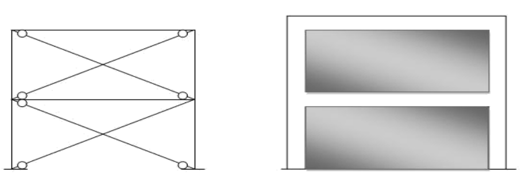

Figure :1

(a):Strutreplacing Infill **(b): Model with Infill Wall**

Modeling of Infill

The masonry wall is replaced by using formulas and expressions given by different researchers. Applying these expressions to a single bay, single storey at once, the study proposes a comparison of the results and indicates the most suitable relation to be used in practical design. The frame was assumed to be fixed the bottom, and the columns and beams of the frame were modeled using two-nodded frame or beam element. Masonry infill was modeled as x-bracing using two nodded element. The transfer of bending moments from frame to masonry wall was prevented by specifying the moment releases at both ends of the struts. Tension compression limits have been used which is available as an option in SAP2000 software. Fig.2 shows details of the diagonal strut.

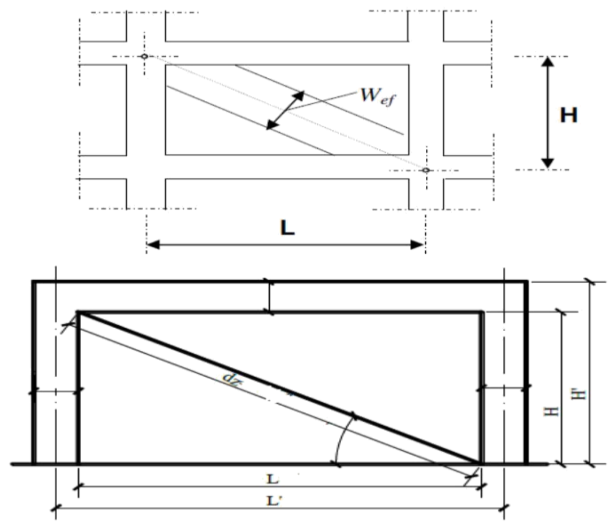

Figure :2 Diagonal Strut replacing infill

i. Holmes (1961)

Holmes states that the width of the equivalent strut to be one third of the diagonal length of infill, which resulted in the infill strength being independent of frames stiffness

$$W = \frac{dz}{3}$$

Where W= Width of the strut

d_z=Diagonal length

ii. Smith and Carter (1969)

Stafford Smith and Carter proposed a theoretical relation for the width of the diagonal strut based on the relative stiffness of infill and frame.

$$W = 0.58 \left(\frac{1}{h}\right)^{-0.445} (\lambda_h H')^{0.335dz} \left(\frac{1}{H}\right)^{0.064}$$

$$\lambda_h = \sqrt[4]{\frac{Em\, t \sin 2\theta}{4Ec\, Ic\, Hm}}$$

Where t, H and E are the thickness, the height and the modulus of the infill respectively. $\boldsymbol{\theta}$ is the angle between diagonal of the infill and the horizontal E is the modulus of elasticity of the column, I_c is the moment of inertia of the columns, H is the total frame height, and h is a dimensionless parameter (which takes into account the effect of relative stiffness of the masonry panel to the frame).

iii. Mainstone(1971)

Mainstone gave equivalent diagonal strut concept by performing tests on model frames with brick infill. His approach estimates the infill contribution both to the stiffness of the frame and to its ultimate strength.

$$W= 0.16d_z\,(\boldsymbol{\lambda}_h)^{-0.3}$$

Infill thickness that is in contact with the frame (t) and the diagonal length (d_z) and an

equivalent width W.

iv. Liaw & Kwan (1984)

Liaw and Kwan proposed the following equation based on experimental and analytical data.

$$W= \frac{0.95\,H\,cos\theta}{\sqrt{\lambda h}\,H'}$$

Where H is Total frame height

v. Decanini & Fantin (1986)

$$W= \left(\frac{0.748}{\lambda h} + 0.085\right)d_m \quad \text{for Uncracked Masonry}$$

$$W= \left(\frac{0.707}{\lambda h} + 0.01\right)d_z \quad \text{for Cracked Masonry}$$

Here d_z is diagonal length; h is dimensionless parameter (which takes into account).

vi. Paulay and Priestley (1992)

$$W=0.25\,d_z$$

W=4

d_z= diagonal length

Smith & Carter and Decanini & Fantin equations generate large values for the diagonal strut width. Mainstone relation is very close to that proposed by the Romanian code, both of them being at the inferior limit. The expressions used in this study for frame considering the stiffness of infill are as follows

$$W=\frac{dz}{4}=1.29\text{m}$$

Conclusion

Strut sizes are obtained and summarized in the Table 1.

Beam (b mm x d mm)	Column (mm x mm)	StrutSize (w mm x d mm)
450X300	600X900	960X250
450X300	900X600	1025X250
450X450	450X450	970X250
450X450	600X900	1035X250
450X450	900X600	1095X250
450X450	600X600	1015X250
600X450	600X900	1415X250
600X450	900X600	1450X250

RESULTS AND DISCUSSIONS

Introduction

The models shown above are subjected to dynamic loads and their results are compared in terms of base shear, roof displacement, inter-story drifts and etc,. The selected models were subjected to nonlinear statics analysis with and without x steel bracings. The stiffness of the infill was modeled by replacing the infill with x masonry bracing. G+11, G+15, G+21 models were analyzed according to the codal provisions.

Pushover Curves

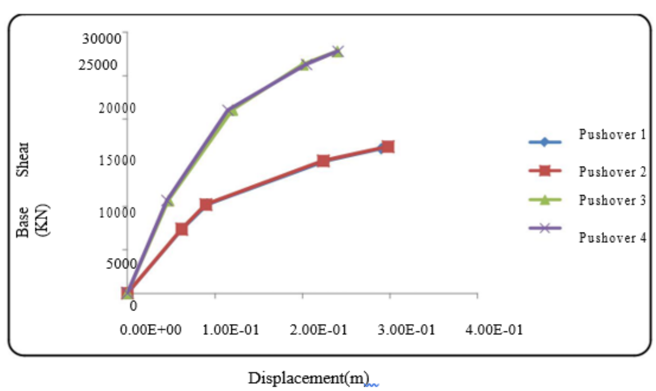

Figure: 3 Pushover Curves for G+ 11 Bare Frames

As from the Fig: 3, it can be concluded that the pushover curves for the pushover case 1 & 2 and pushover case 3 & 4 are quite identical. The structure performs better when it is subjected to acceleration load pattern as it is able resist more lateral loads than in mode lod pattern.

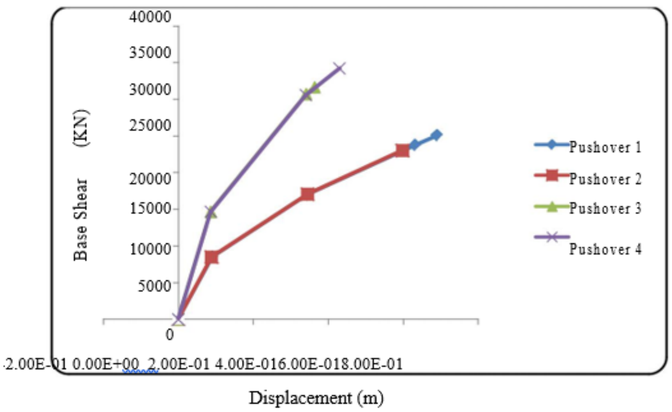

Figure: 4 Pushover Curve for G+ 21 Bare Frames

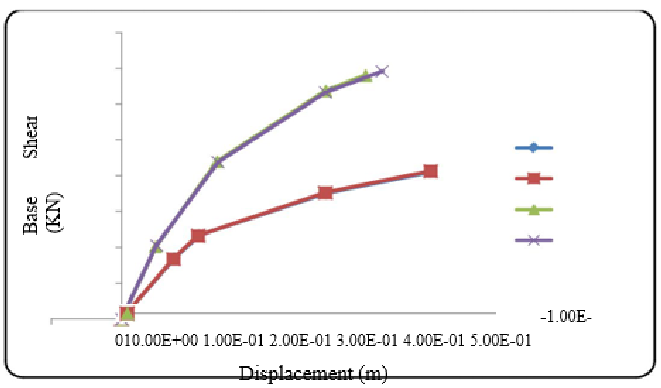

Figure: 5 Pushover Curve for G+ 15 Bare Frames

As observed in prior Fig: 3,4,5, of G+11 bare frames even here the pushover curves for 1,2 and 3,4 are identical. Therefore, only two pushover cases will be taken into consideration for further comparison of pushover curves. The pushover curves are compared with or without the lateral resisting system i.e., bracing and x masonry bracing.

Results

Base Shear: Base shear values for G+11, G+15, G+21 buildings are listed according to pushover case 1, 2, 3, 4 and they are compared with bare frame model to determine the percentage of change is base shear.

Table: 3Base shear for G+11 Storied Building

Story	Bare Frame	Masonry X Bracing	% Change	Steel X Bracing	% Change
Pushover 1	16356	18200	11	36713	224
Pushover 2	16409	18221	11	36660	223
Pushover 3	26046	27591	6	49430	189
Pushover 4	26096	26602	2	49353	189

Table: 4 Base shear for G+15 Storied Building

Story	Bare Frame	Masonry X Bracing	% Change	Steel X Bracing	% Change
Pushover 1	18859	19595	4	42961	227
Pushover 2	18935	19670	4	42909	226
Pushover 3	29909	31106	4	59182	197
Pushover 4	29720	30984	4.2	58995	198

Table: 5 Base shear for G+21 Storied Building

Story	Bare Frame	Masonry X Bracing	% Change	Steel X Bracing	% Change
Pushover 1	21069	24015	11	45476	215
Pushover 2	21130	24049	14	45426	214
Pushover 3	31890	37078	16	61447	192
Pushover 4	31980	37071	16	61710	193

CONCLUSIONS

Summary

In this study, first of all the following conclusions have been made for G+11, G+15, G+20 vertically irregular storied building with and without x masonry based on the results and observations. The structures were analyzed by carrying out pushover analysis with four pushover cases.

Conclusions

Base Shear capacity of the structure increases for x masonry bracing and x steel bracing than bare frame and the percentage change in base shear is 11% & 6% with x masonry pushover cases. It increases by 224% & 189% for steel braced structure for respective pushover cases.

Base Shear of the G+15 storied structure also increases as it did for the G+11 storied structure; the increment is seen as 4% & 4% for x masonry structure pushover cases and 227% & 198% for x steel bracing pushover cases.

Roof displacement for G+11 x masonry and x steel braced structures the percentage changes observed were 6% & 39%. Roof displacement of the structures decreases with provision of bracings; the percentage changes observed to that of bare frame are 6% & 22% with x masonry and steel bracing respectively for G+15 storied structure. Time period of G+11 storied structure varies as 1.6638, 1.5895 & 1.04051seconds for bare frame, x masonry bracing & x steel bracing respectively. Time period of the structure decreases with increase in the stiffness, with 2.75488 seconds for a bare frame to 2.59755 & 1.96806 seconds for structure with x masonry and steel bracing for G+21 story structure respectively.

Future Scope

Pushover analysis has been extensively performed on the regular building but considerably less work has been done on structures with vertical irregularity. Response to the dynamic event is not that predictable for vertical irregular structures they don't behave as the regular structure does, so more work has to be carried on these structures to study their behavior. Study of the intricate details of the irregular structure has been the pivotal aim of this study.

The study can be elaborated for the structures with irregularity by,

1 Introduction of different types of lateral resisting systems with higher mode shapes accounting for its behavior.

2 Applying different pushover analyses some of which could be energy based pushover analysis, adaptive pushover analyses as these are modified analyses than conventional pushover analysis.

3 Considering different type of irregularities such as mass, stiffness, in plane discontinuity of lateral loads resisting members etc.

REFERENCES

1. Sermin, O., "Evaluation of Pushover Analysis Procedures for Frame Structures", Middle East Technical University.
2. Ghaleb, R., "Nonlinear Time History and Push-Over Extended 3D Analyses For Seismic Design and Evaluation", University of Civil Engineering Bucharest.
3. Rasmita, T., "Pushover Analysis of R/C Setback Building Frames", National Institute of Technology Rourkela, August 2012.
4. Rohit, B., (2011), "Pushover Analysis of Reinforced Concrete Frame", Thapar University.
5. Aswin, T., "Seismic Evaluation of 4-Story Reinforced Concrete Structure by Non-Linear Static Pushover Analysis", National Institute of Technology Rourkela.
6. ATC 40, "Seismic Evaluation and Retrofit of Concrete Buildings", California Seismic Safety Commission.
7. Ravi, K., Babu, N., Prashanth, H., Manjunatha, B., and Venkat, R., (2012), "Seismic Performance Evaluation of RC Buildings with Vertical Irregularity", ISET-Paper No. E012.
8. Chatpan, C., and Anil, K., (2006), "Evaluation of Modal Pushover Analysis Using Vertically Irregular Frames", Vol. 3, No. 3, Maharastra, 21-39.
9. Devesh, P., and Bharat, B., (2006), "Qualitative Review Of Seismic Response Of Vertically Irregular Building Frames", ISET Journal of Earthquake Technology, Technical Note, Vol. 43, No. 4, December 2006, 121-132.
10. Khoshnoudian, F., and Mohammadi, S., (2008), "Seismic Response Evaluation Of Irregular High Rise Structures by Modal Pushover Analysis", WCEE.